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ASSESSING THE IMPACT OF ABILITY-BASED PAIRING STRATEGIES IN TEAM TRAINING OF A COMPLEX SKILL

ERIC ANTHONY DAY

University of Oklahoma
455 W. Lindsey, Room 705
Norman OK 73019-2007

WINFRED ARTHUR, JR.
SUZANNE T. BELL
BRYAN D. EDWARDS

Texas A&M University
College Station TX 77843

WINSTON BENNETT, JR.

Air Force Research Laboratory
Warfighter Training Research Division
6030 South Kent Street
Mesa AZ 85212-6061

JORGE L. MENDOZA

University of Oklahoma
1000 Asp Avenue
Norman OK 73019-4076

TRAVIS C. TUBRÉ

Texas A&M University
College Station TX 77843

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Human Effectiveness Directorate
Warfighter Training Research Division
6030 South Kent Street
Mesa AZ 85212-6061

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// Signed //

WINSTON BENNETT JR
Project Scientist

// Signed //

HERBERT H. BELL
Technical Advisor

// Signed //

CURTIS J. PAPKE, Colonel, USAF
Chief, Warfighter Training Research Division

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*Eric Anthony Day, **Winfred Arthur, Jr., **Suzanne T. Bell, **Bryan D. Edwards, ***Winston Bennett, Jr., *Jorge L. Mendoza, and **Travis C. Tubré,

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*University of Oklahoma
455 W. Lindsey, Room 705
Norman OK 73019-2007
**Texas A&M University
College Station TX 77843

***Air Force Research Laboratory
Warfighter Training Research Division
6030 South Kent Street
Mesa AZ 85212-6061

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Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Training Research Division
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14. ABSTRACT

In this study, we created homogeneous and heterogeneous dyadic training teams on the basis of g to examine how team composition affects the acquisition and performance of a complex skill at both team and individual levels. Specifically, 176 young adult males completed 10 hours of training on a complex skill involving strong cognitive and psychomotor demands. Participants practiced in pairs and completed tests of both team and individual performance. We found a strong additive influence of ability on team performance. Uniformly high-ability teams outperformed mixed-ability teams, who in turn outperformed uniformly low-ability teams. At the individual level, high-ability trainees acquired significantly more skill when paired with other high-ability partners instead of low-ability partners; however, low-ability trainees benefited only slightly from being paired with high-ability partners.

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PREFACE

This research was sponsored under USAF Contract Number F41624-95-C-5007, awarded to Winfred Arthur, Jr. from the U.S. Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Training Research Division, Mesa, AZ.

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Correspondence concerning this manuscript should be sent to: Eric Day, Department of Psychology, The University of Oklahoma, 455 W. Lindsey, Room 705, Norman, OK, 73019-2007; Phone: 405-325-3237; E-mail: eday@ou.edu; Fax: 405-325-4737.

ASSESSING THE IMPACT OF ABILITY-BASED PAIRING STRATEGIES IN TEAM TRAINING OF A COMPLEX SKILL

Teams have received a great deal of research attention in the industrial and organizational psychology literature. Within this literature, several approaches to creating teams have been proposed including guidelines for team training (Cannon-Bowers & Salas, 1998; Swezey & Salas, 1992). Whether focusing on team or individual performance, the importance of issues related to team dynamics, such as team composition, becomes salient when considering team training (Driskell, Hogan, & Salas, 1987). However, inadequate attention has been paid to optimal team compositions in training contexts, particularly those involving complex skills. Accordingly, the central focus of the present study was to investigate the role of general cognitive ability (*g*) when used to compose training dyads on a systematic, *a priori* basis. Specifically, we created high- (HH), low- (LL), and mixed- (HL) ability teams on the basis of *g* to examine how team composition affects the learning and performance of a complex skill at both team and individual levels. At the team level, we sought to examine the potential synergistic effects of homogeneously high-ability teams. At the individual level, we explored the extent to which trainees were influenced by the ability of their partners.

Ability-Based Team Composition Effects

Substantial empirical evidence has indicated that, under a variety of conditions, team members' ability is predictive of team performance. However, the observed relationships vary according to the operationalization of team-ability and the type of task employed (Devine & Philips, 2001). Moreover, although several recent studies have examined team composition effects on performance (e.g., Barrick, Stewart, Neubert, & Mount, 1998; LePine, 2003; Neuman & Wright, 1999), the primary limitation of the existing research is that team composition has generally been examined on a *post hoc* basis. The results of an extensive literature search indicated that only a handful of studies (e.g., Goldman, 1965; Graham & Dillon, 1974; Tziner & Eden, 1985) have formally examined the effects of *a priori* determined team or group compositions on resulting performance. Of these studies, Tziner and Eden's (1985) work is often cited in the team composition literature as their findings reflected both additive as well as synergistic effects for team ability.

Tziner and Eden (1985) experimentally manipulated the ability composition of three-person tank crews in a field setting. Although additive effects were found for heterogeneous teams, teams that were uniformly high in ability performed significantly better than that predicted from team-member abilities. Similarly, teams that were uniformly low in ability performed considerably worse than expected from team-member abilities. In the discussion of their findings, Tziner and Eden (1985) stated that team performance is "likely to relate positively to the summed abilities of all group members" (p. 90). Furthermore, they also emphasized that synergistic effects can occur when a team is composed of all highly capable individuals. Specifically, they suggested that, as long as uniformly low-ability teams can be avoided, "talent [ability] is used more effectively when concentrated than spread around" (p. 91).

Although researchers have discussed the importance of studying nonadditive composition effects in teams (e.g., Moreland, Levine, & Wingert, 1996), nonadditive effects like those obtained by Tziner and Eden (1985) are rare in the literature. Indeed, the importance of Tziner and Eden's study is evident as researchers (e.g., LePine, 2003) almost exclusively point to Tziner and Eden's results when making statements about the potential synergistic effects of ability in teams. Thus, we believe it is worthwhile to both replicate and extend Tziner and Eden's findings. Accordingly, the overriding purpose of this investigation was to examine the effects associated with an *a priori* manipulation of the ability composition of dyadic training teams. Not only were we interested in replicating the synergistic effects demonstrated by Tziner and Eden, we also sought to extend their study in several ways. First, we used a laboratory task that yielded objective performance scores, whereas Tziner and Eden used subjective rankings of performance made by supervisors. Second, in contrast to Tziner and Eden's single assessment of performance, we assessed performance periodically during training. Through a longitudinal assessment, we were able to examine the effects of ability composition on overall performance as well as performance growth curves. Lastly, in addition to examining the effects of ability composition on team performance, we also examined the effects of ability composition on individual performance (i.e., skill acquisition).

With respect to replicating and extending Tziner and Eden's (1985) findings regarding ability composition and team performance, we expected higher-ability teams to achieve higher levels of performance compared to lower-ability teams. We also sought to examine whether the synergistic gains of creating uniformly high-ability teams would be greater than the inordinate losses associated with uniformly low-ability teams. Therefore, we examined the following team-level hypotheses.

H1: Uniformly high-ability teams will have higher team performance scores than mixed-ability teams, who in turn will have higher team performance than uniformly low-ability teams.

H2: The difference in team performance scores between uniformly high-ability teams and mixed-ability teams will be greater than the difference between mixed-ability teams and uniformly low-ability teams.

In addition, we expected performance growth curves to differ as a function of the ability composition of teams. In an extensive review of the literature on abilities and training, Fleishman and Mumford (1989) indicated that high-ability individuals not only achieve higher levels of overall performance during training, but they also develop skill more rapidly than low-ability individuals. Based on these effects, we tested the following, team-level hypothesis.

H3: Higher-ability teams will achieve higher levels of team performance at a faster rate than lower-ability teams.

Ability-Based Pairing Strategies and Individual Learning

It is not uncommon in the military for training teams to disband after training. For their post-training assignments, including active military duty, individuals are frequently reassigned to other teams and paired with partners with whom they had no contact during training. Team composition changes over time and individuals find themselves performing alongside different teammates. Considering that a team's performance is largely determined by the competency of its individual members (Salas, Bowers, & Cannon-Bowers, 1995), it is important to examine the effects of team training at the individual level as well as the team level. Therefore, another important purpose of the present study was to examine the extent to which trainees' individual levels of skill acquisition were influenced by the ability of their training partners.

An extensive literature search revealed only a handful of studies that have manipulated the ability composition of groups or teams on an *a priori* basis and compared the influence of heterogeneous versus homogeneous compositions on resulting individual performance. For example, Dossett and Hulvershorn (1983) demonstrated that using ability-based pairing strategies could increase the efficiency of Air Force technical training using computer assisted instruction. Specifically, they noted that heterogeneous pairing strategies increased the amount of time needed to complete training for high-ability trainees, but heterogeneous pairings did not reduce training time for low-ability trainees. In a study involving military paramedical training, Brooks, Ebner, Manning, and Balson (1985) found that heterogeneous pairings were beneficial to low-ability members of a learning dyad, but deleterious to high-ability members.

Although there is a dearth of studies examining *a priori* ability compositions of training teams, the growing literature on cooperative learning strategies in elementary and secondary education can offer insight into the optimal ability compositions of training teams (see Hooper, 1992; Hooper, Temiyakarn, & Williams, 1993; Webb, Nemer, Chizhik, & Sugrue, 1998). Advocates of heterogeneous ability groupings claim that, along with its potential positive affective consequences, heterogeneous ability groupings have important positive cognitive consequences as well (Slavin, 1990), especially when tutor-tutee relationships exist among group members (Webb, 1982a, 1982b). The contention is that high-low pairings result in favorable outcomes for both high- and low-ability students. However, skeptics suggest that heterogeneous groupings fail to challenge high-ability students (Willis, 1990) and that less able students benefit at the expense of their more able partners (Mills & Durden, 1992; Robinson, 1990).

Consistent with the mixed opinions regarding the relative superiority of heterogeneous versus homogeneous groupings, the empirical research offers mixed findings with some studies indicating that heterogeneous groupings lead to better achievement for both low- and high-ability students (e.g., Beane & Lemke, 1971; Larson et al., 1984; Webb, 1980) and other studies indicating that low-ability students benefit from heterogeneous groupings while the achievement of high-ability students suffers (Dar & Resh, 1986; Hooper & Hannafin, 1988; Webb et al., 1998). With respect to heterogeneous groupings, researchers have also suggested that the benefits for low-ability students are significantly larger than the losses incurred by high-ability students (Dar & Resh, 1986; Webb et al., 1998). In fact, recent meta-analyses of field studies in cooperative learning (Lou, Abrami, & Spence, 2000; Lou et al., 1996) have shown that the achievement of low-ability students increases by approximately one half a standard deviation in heterogeneous groupings compared to homogeneous groupings while the achievement of high-ability students is not differentially influenced by grouping strategy.

However, recent research has also suggested that the effects of cooperative learning may be moderated by the age of the learner and task complexity. First, the effects of cooperative learning may be smaller in adult populations (Lou et al., 2000). Second, for complex tasks, low-ability learners may not benefit from heterogeneous groupings and high-ability learners may learn less when placed with low-ability partners instead of high-ability partners (Fuchs, Fuchs, Hamlett, & Karns, 1998). The differences in results for complex tasks may stem from the quality of interactions that take place between partners during training. For instance, homogeneous pairings for high-ability individuals may foster cognitive collaboration, including sharing creative solutions, discussing alternatives, and resolving differences in ideas (Fuchs et al., 1998). Within heterogeneous pairings, cognitive collaboration may be stifled with low-ability individuals sometimes confusing high-ability partners and high-ability individuals having difficulty explaining task complexities to low-ability partners (Fuchs et al., 1998).

Therefore, continued research that examines the effects of *a priori* team composition manipulations on individual learning with adult populations and complex tasks will inform training practitioners on how to optimally group trainees into training teams. Accordingly, the present study was designed to address a number of individual-level hypotheses. Given that it has been well established that *g* is a valid predictor of complex skill acquisition and training success (Fleishman & Mumford, 1989; Ree & Earles, 1991) and much of the research on cooperative learning generally suggests that learning is enhanced when individuals are paired with high-ability partners, we examined the following hypotheses.

H4: High-ability trainees will have higher individual performance scores than low-ability trainees.

H5a: Individuals who train with high-ability partners will have higher individual performance scores than individuals who train with low-ability partners.

However, based on Fuchs et al.'s (1998) conclusions regarding cooperative learning for complex tasks and the synergistic performance effects of homogeneously high-ability teams demonstrated by Tziner and Eden (1985), we expected only high-ability trainees to benefit from training with a high-ability partner. Accordingly, we examined the following, more specific hypotheses.

H5b: High-ability individuals who train with high-ability partners will have higher individual performance scores than high-ability individuals who train with low-ability partners.

H5c: Low-ability individuals who train with high-ability partners will not have higher levels of individual performance compared to low-ability individuals who train with low-ability partners.

We also expected individual performance growth curves to differ as a function of trainee and partner ability. Therefore, we tested the following hypotheses.

H6: High-ability trainees will achieve higher levels of individual performance at a faster rate than low-ability trainees.

H7: The skill acquisition of high-ability individuals who train with high-ability partners will be faster than the skill acquisition of other trainees.

We were also interested in how the ability composition of training teams affects the nature of team member interactions and how these interactions during team training are related to individual skill acquisition. Specifically, we expected individual perceptions of communication, leadership, and cohesion to differ as a function of pairing strategy. In particular, we were interested in contrasting individual perceptions found in members of mixed-ability training teams to those found in homogeneous teams. Consistent with Fuchs et al.'s (1998) conclusions regarding how low-ability individuals sometimes confuse high-ability partners and high-ability individuals have difficulty explaining task complexities to low-ability partners, we tested the following hypothesis regarding communications in training teams.

H8: Individuals who train in mixed-ability teams will rate the quality of communication in their teams lower compared to trainees in homogeneous teams.

We also expected to find differences in the perceived leadership in mixed-ability teams compared to homogeneous teams. In contrast to homogeneous teams, differences in individual competency should be readily apparent among mixed-ability teams with high-ability partners gaining more expert power (French & Raven, 1959) than low-ability partners. Subsequently, high-ability individuals would be more likely to emerge as leaders in training teams than low-ability individuals. Thus, we tested the following hypotheses.

H9: Low-ability individuals who train with high-ability partners will rate their partners stronger in leadership than other trainees.

H10: High-ability individuals who train with low-ability partners will rate themselves stronger in leadership than other trainees.

Consistent with social exchange models of attraction (Thibaut & Kelley, 1959), we posited that high-ability individuals who train with low-ability partners would find working in dyadic teams the least rewarding and would subsequently experience the least cohesion in their teams. High-ability trainees working in mixed-ability teams may even become annoyed or angered by their less capable partners (Secord & Backham, 1974). Therefore, we tested the following hypothesis.

H11: High-ability individuals who train with low-ability partners will rate the degree of cohesion in their dyads lower compared to other trainees.

In general, we expected positive relationships between individual skill acquisition and ratings of communication, leadership, and cohesion. However, we were particularly interested in the strength of the relationships found in the mixed-ability teams for communication and leadership. The willingness of high-ability partners to exchange information and provide clear explanations would be critical to the successful improvement of task understanding and skill for low-ability trainees. Furthermore, learning for low-ability trainees would be contingent upon their willingness to seek advice, clarification, and direction from their higher-ability partners. In a similar vein, it would be important for high-ability individuals to take charge of the training situation to ensure that their lower-ability partners did not unduly hinder their teams' progress or their own skill development. Thus, we tested the following hypotheses.

H12: The communication-performance relationship will be stronger for low-ability individuals who train with high-ability partners than for all other trainees.

H13: Self-ratings of leadership will be more strongly related to individual performance for high-ability individuals who train with low-ability partners than for all other trainees.

H14: Partner-ratings of leadership will be more strongly related to individual performance for low-ability individuals who train with high-ability partners than for all other trainees.

Method

Participants

An initial sample of 1266 male volunteers from a large southwestern university was recruited using advertisements in the university newspaper, announcements in classrooms, and posted notices around campus. Participants were required to be at least 18 years of age. Also, due to hardware constraints, only right-handed volunteers could participate in the study. Of 1266 individuals screened, 194 were selected on the basis of their *g* scores. Eighteen of the selected participants did not complete the study, resulting in an attrition rate of 9%. Chi-squares indicated no differences in attrition across the three levels of team ability. As a result of screening and attrition from the study, the final sample size was 176, which translated into 88 training dyads (i.e., 29 HH, 32 HL, and 27 LL dyads). The mean age of the final sample was 19.62 (SD = 2.30). Participants who completed the study were paid $75, and participants who were not selected were paid $5 for the screening session. Participants also competed for bonuses of $100, $60, and $40, which were awarded to the top three performing teams.

Measures

Raven's Advanced Progressive Matrices (APM; Raven, Raven, & Court, 1994). The APM is a measure of *g* that consists of 36 matrix problems arranged in an ascending order of difficulty. The APM is scored by summing the number of problems correctly answered. We used an administration time of 40 minutes. The test manual reports a test-retest reliability of .91 for the APM scores. We obtained a Spearman-Brown odd-even split-half reliability of .84 for the APM scores. Scores on the APM were used to select participants into the study and also to create the different ability pairings.

Space Fortress. The performance task used in the present study was the video game Space Fortress (Donchin, 1989; Mane & Donchin, 1989). Space Fortress is "an experimental game which was designed to simulate a complex and dynamic aviation environment" (Gopher, 1993, p. 299). Space Fortress represents important information processing demands that are present in aviation and other complex tasks (Gopher, Weil, & Bareket, 1994; Hart & Battiste, 1992). These processing demands include short- and long-term memory loading, high workload, dynamic attention allocation, decision-making, prioritization, resource management, discrete motor responses, and difficult manual control elements (Gopher, Weil, & Siegel, 1989). Laboratory rooms were equipped with a table, a computer and monitor, a right-hand joystick, a three-button mouse for the left hand, and two right-handed chair desks. In Space Fortress, trainees control a space ship's flight path using the joystick and shoot missiles with a trigger on the joystick. A fortress is located center-screen with two concentric hexagons surrounding it. An information panel at the bottom of the screen indicates fortress vulnerability, which changes with each missile hit. Friend and foe mines fly in the space surrounding the fortress and are identified by a mine indicator on the information panel. To destroy foe mines, trainees are required to push an "identify friend or foe" mouse button at the appropriate time. Symbols appear on the screen just below the fortress to indicate opportunities to gain bonus points or additional missiles by pushing either a "points" or "missiles" mouse button at the appropriate time. Also, the information panel shows the number of available missiles, a battle score, and component scores based on ship velocity, ship control, and the speed of dispatching mines. The screen displays a total score, which is a composite of the others, along with more detailed performance feedback at the end of each game. A more detailed description of Space Fortress can be found in Arthur et al. (1995).

Perceptions of team interactions. We developed a 13-item paper-and-pencil instrument to measure individual perceptions of the interactions that took place within dyadic training teams. We selected and adapted the items from previous instruments (i.e., Barry & Stewart, 1997; Morgan, Glickman, Woodard, Blaiwes, & Salas, 1986) to assess communication (four items), leadership (two items), and sense of cohesion (seven items). Trainees were instructed to rate the extent to which each item was descriptive of himself and his partner with respect to their interactions as a team. Thus, each trainee made separate responses for himself and his partner. Responses to all the items were made on a 5-point scale (1 = to a very little extent; 5 = to a very great extent). Examples of communication items included "has a chance to express opinions" and "listens to the other's input." The leadership items included "assumes a leadership role" and "acts as team leader." Examples of cohesion items included "has a feeling of unity and cohesion within the team" and "works well with partner." The instrument was administered on four separate occasions during training. The average coefficient alpha for self-ratings was .71 for communication, .91 for leadership, and .92 for cohesion. The average coefficient alpha for partner-ratings was .70 for communication, .89 for leadership, and .92 for cohesion. Across the four administrations and both ratings of self and partner, the average correlation between different administrations of the same scale (i.e., test-retest reliabilities) were .58 for communication, .71 for leadership, and .69 for cohesion.

Design and Procedure

Performance on the APM was used to select participants into the study and also to create the different ability groups. Individuals were retained if they scored 21 or lower or 27 or higher on the APM. These cut-off scores represented one standard error of measurement (SEM) above and below the mean APM score based on a sample ($N = 496$) consisting of 363 participants who completed the APM for a prior study (Arthur & Woehr, 1993) and 133 participants comprising the first screening group for the present study. Using this approach ensured that the low- and high-ability participants would indeed be categorically different.

Following screening, three sets of training teams were created on the basis of the participants' general cognitive ability scores. Teams were composed of dyads who were both high (HH), both low (LL), or mixed (HL) in terms of their ability. Assignment of partners was random within ability level, and trainees were assigned to the same partner throughout training.

Table 1 provides an overview of the training and data collection procedures. Upon selection, trainees participated in 10 days of training extended over two weeks. On Monday of the first week, trainees began with 20 minutes of videotaped instructions that explained the rules of Space Fortress. They were also informed of four strategies on how to perform Space Fortress (Frederiksen & White, 1989). Trainees then performed two team and two individual 3-minute games of Space Fortress (session 1). This was followed by a 5-minute review video of the instructions and strategies. Following this review, trainees underwent 11 more Space Fortress training sessions that took place over the next 13 days. Trainees completed the team interaction scales after sessions 2, 5, 7, and 12.

Table 1. Overview of Training and Data Collection Procedures

Day	Activity	# of team practice games	# of team test games	# of individual test games
Screening	• Consent forms Raven's APM			
First week of training				
Monday	• Instructions • SF session 1 • Summary of instructions	0	2	2
Tuesday	• SF session 2 • Team interactions administration 1	6	2	2
Wednesday	• SF session 3	6	2	2
Thursday	• SF session 4	6	2	2
Friday	• SF session 5 Team interactions administration 2	0	2	2
Second week of training				
Monday	• SF session 6	0	2	2
	• SF session 7 • Team interactions administration 3	0	2	2
Tuesday	• SF session 8	6	2	2
Wednesday	• SF session 9	6	2	2
Thursday	• SF session 10	6	2	2
Friday	• SF session 11	0	2	2
	• SF session 12 Team interactions administration 4	0	2	2

Note. APM = Advanced Progressive Matrices. SF = Space Fortress.

During a standard training session, dyadic teams performed six practice games together followed by two team test games. Trainees were informed that the monetary bonuses would be determined by their scores on the team test games, but their individual performance would also be evaluated. Hence, after every pair of team test games, trainees also completed a pair of individual test games. All games lasted 3 minutes. When performing as a team, trainees performed with their partner—one trainee, using his left hand, controlled all functions related to the mouse (copilot mine-missile manager), and the other trainee, using his right hand, controlled all functions related to the joystick and trigger (pilot-gunner). Trainees alternated roles, which called for physically switching places at the end of each game. Communication between trainees was encouraged. Trainees controlled both the mouse and joystick functions when performing their individual test games. A typical training and testing session lasted approximately 1 hour, and trainees were scheduled to train at the same 1-hour slot for their two weeks of participation. For each session, team performance was operationalized as the mean of the total scores from the pair of team test games; likewise, individual performance was operationalized using the mean from the pair of individual test games.

Results

Team Performance

Table 2 presents the descriptive statistics for team performance for each ability condition. The results are further illustrated in Figure 1. A three (ability composition: LL, HL, or HH) × 12 (sessions 1 through 12) mixed analysis of variance (ANOVA) revealed a statistically significant between-subjects main effect for ability composition, F (2, 85) = 13.39, $p < .001$, $\eta^2 = .24$. The mean team test performance was 1243.80 (SD = 1155.77), 1905. 28 (SD = 1346.63), and 2925.17 (SD = 1154.34) for LL, HL, and HH teams, respectively. In support of Hypothesis 1, higher team ability was associated with higher team performance. Moreover, the results were consistent with Hypothesis 2—the difference between HH teams and HL teams (t (59) = 3.16, $p < .01$, d = 0.81) was greater than the difference between HL and LL teams (t (57) = 2.00, $p < .05$, d = 0.52). However, the results of a direct comparison of these differences did not reach conventional levels of statistical significance, z = 1.41, $p < .08$ (one-tailed). Thus, the results only offered mixed support for Hypothesis 2.

The results also indicated a statistically significant within-subjects main effect, F (11, 935) = 407.09, $p < .001$, $\eta^2 = .83$. Teams' improved their performance across training sessions. In addition, the results revealed a statistically significant interaction between ability composition and training session, F (11, 935) = 3.87, $p < .001$, $\eta^2 = .08$. In support of Hypothesis 3, higher-ability teams achieved higher levels of performance at a faster rate than lower-ability teams.

We used the SAS MIXED procedure (SAS Institute Inc., 1999) to further explore the extent to which growth curves differed as a function of ability composition. The results indicated that both the linear and quadratic trends differed as a function of ability composition. Specifically, both the linear (t (962) = 3.41, $p < .05$) and quadratic (t (962) = 2.47, $p < .05$) trends were stronger for HH teams (linear b = 1520.58; quadratic b = –76.81) than for LL teams (linear b = 1067.20; quadratic b = –53.02). The linear trend (b = 1347.05) was also stronger for HL teams than for LL teams (t (962) = 2.16, $p < .05$), but the difference in quadratic trends was not statistically significant between the HL ($b = -65.62$) and LL teams (t (962) = 1.34, $p > .10$). No statistically significant differences were observed between the HH and HL teams. In sum, uniformly high-ability teams improved their performance at a faster rate and approached performance plateaus sooner compared to uniformly low-ability teams, and mixed-ability teams improved their performance at a faster rate and approached performance plateaus at the same rate compared to uniformly low-ability teams.

Table 2. *Means and Standard Deviations of Team Performance Across Sessions and by Ability Composition*

	Ability Composition					
	HH		HL		LL	
SF team test performance	*M*	*SD*	*M*	*SD*	*M*	*SD*
Session 1	-1478.19	705.03	-2137.36	665.29	-1888.89	679.28
Session 2	869.43	1173.40	154.81	1126.36	-55.63	863.82
Session 3	1907.64	1360.88	1010.33	1229.46	416.25	1061.19
Session 4	2801.21	1307.74	1688.28	1614.51	977.36	1049.31
Session 5	3001.02	1277.08	1815.81	1515.11	1098.53	1019.42
Session 6	3337.86	1332.56	2126.53	1509.61	1385.68	1319.38
Session 7	3644.97	1393.49	2451.45	1718.82	1668.04	1336.10
Session 8	3969.28	1341.68	2766.16	1578.89	1912.46	1679.18
Session 9	4039.14	1570.89	2970.35	1911.75	2014.51	1870.45
Session 10	4185.19	1394.19	3211.98	1644.86	2520.01	1671.98
Session 11	4346.07	1358.84	3304.11	1633.58	2487.74	1517.71
Session 12	4478.38	1319.64	3500.89	1641.85	2389.50	1793.44

Note. SF = Space Fortress. HH = two high-ability teammates ($n = 29$). HL = one high-ability and one low-ability teammate ($n = 32$). LL = two low-ability teammates ($n = 27$).

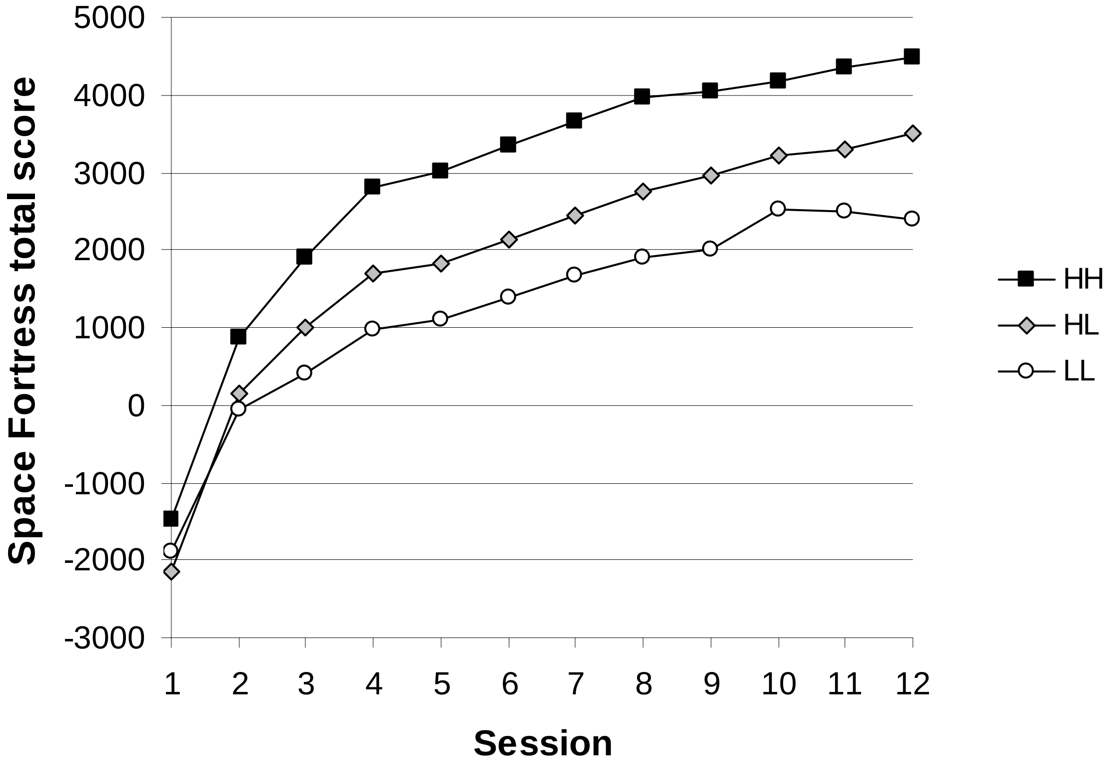

Figure 1. Mean team Space Fortress test scores across sessions as a function of ability composition. HH = two high-ability teammates. HL = one high-ability and one low-ability teammate. LL = two low-ability teammates.

Individual Performance

For the analyses involving individual skill acquisition, we divided the mixed-ability teams into two conditions—those where a high-ability trainee was paired with a low-ability trainee (H_L) and those where a low-ability trainee was paired with a high-ability trainee (L_H)—yielding four different training conditions (H_H, H_L, L_H, and L_L). Table 3 presents the descriptive statistics for individual performance for each training condition. The results are further illustrated in Figure 2. Because individuals were nested in dyadic teams, we used the SAS MIXED procedure to examine the skill acquisition effects at the individual level and treated dyadic team as a random effects variable. Indeed, the results revealed a statistically significant effect for dyadic team ($z = 4.73$, $p < .001$), indicating that our individual participants should be treated as nested within their respective dyadic teams[1]. We then examined fixed effects for individual ability (high versus low), partner ability (high versus low), session (1 through 12), and all corresponding interactions. The results indicated a statistically significant between-subjects main effect for individual ability, $F(1, 116) = 28.99$, $p < .001$, $\eta^2 = .20$. In support of Hypothesis 4,

[1]We conducted similar analyses taking into account the actual performance of individuals' dyadic teams. The results indicated weaker effects for team performance, $z = 1.40$, $p = .08$.

high-ability trainees acquired more skill than low-ability trainees (*d* = 0.83). Results also indicated a statistically significant between-subjects main effect for partner ability, $F\ (1,116) = 3.82$, $p = .05$, $\eta^2 = .03$. In support of Hypothesis 5a, trainees with high-ability partners acquired more skill than trainees with low-ability partners (*d* = 0.30). The overall interaction between individual ability and partner ability was not significant, $F\ (1,116) = 0.78$, $p = .38$.

Table 3. *Means and Standard Deviations of Individual Performance Across Sessions and by Partner Assignment*

	Partner assignment							
	H_H		H_L		L_H		L_L	
SF individual test performance	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Session 1	-841.60	1196.68	-1501.61	1394.85	-1748.95	904.55	-1506.26	1295.95
Session 2	775.53	1166.64	321.60	1257.74	-304.31	1397.28	-409.36	1267.87
Session 3	1556.82	1505.88	1016.45	1432.08	348.77	1379.43	216.94	1130.54
Session 4	2370.56	1520.64	1708.64	1730.89	687.54	1414.99	609.07	1430.56
Session 5	2564.33	1535.08	1910.72	1643.48	1118.94	1733.55	914.10	1438.70
Session 6	2875.57	1538.97	2188.61	1573.43	1307.23	1801.91	971.47	1578.63
Session 7	3051.59	1645.26	2307.23	1648.33	1769.84	1777.65	1352.47	1637.17
Session 8	3435.66	1567.78	2864.52	1683.76	1976.02	1963.32	1687.06	1813.27
Session 9	3560.53	1662.76	2905.08	1775.33	2009.02	1939.89	1604.05	1908.16
Session 10	3931.40	1505.04	3252.95	1626.09	2445.02	1886.57	2168.77	1829.86
Session 11	3940.98	1534.43	3367.08	1612.87	2415.84	1847.45	2082.86	1926.90
Session 12	4112.22	1512.72	3454.48	1572.76	2641.69	2032.11	2163.87	1924.05

Note. SF = Space Fortress. H_H = high-ability trainees assigned to high-ability partners (*n* = 58). H_L = high-ability trainees assigned to low-ability partners (*n* = 32). L_H = low-ability trainees assigned to high-ability partners (*n* = 32). L_L = low-ability trainees assigned to low-ability partners (*n* = 54).

Although the preceding analyses did not reveal an interaction between individual ability and partner ability, we conducted planned comparisons to more closely examine Hypotheses 5b and 5c. Accordingly, we conducted two separate sets of analyses and compared H_H to H_L

trainees and L_H to L_L trainees (taking into account the random effects of dyadic team). Table 4 shows the results of these comparisons. In support of our hypotheses, an overall statistically significant difference in skill acquisition was found between H_H and H_L trainees (d = 0.47), but the overall difference between L_H and L_L trainees was not statistically significant (d = 0.16).

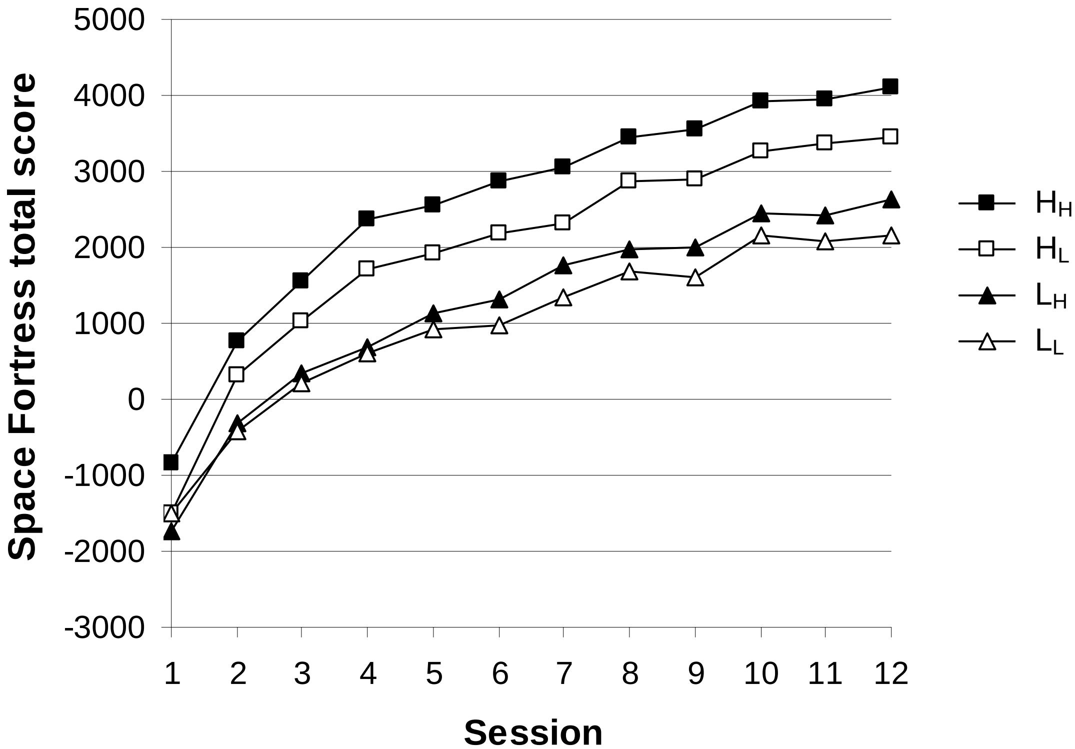

Figure 2. Mean individual Space Fortress test scores across sessions as a function of trainee and partner ability. H_H = high-ability trainees assigned to high-ability partners. H_L = high-ability trainees assigned to low-ability partners. L_H = low-ability trainees assigned to high-ability partners. L_L = low-ability trainees assigned to low-ability partners.

The results of the within-subjects main effect indicated that trainees' performance improved across training sessions, F (11, 1948) = 139.71, p < .001, η^2 = .44. Additionally, the results revealed a statistically significant interaction between individual ability and training session, F (11, 1948) = 3.72, p < .001, η^2 = .02. In support of Hypothesis 6, high-ability trainees achieved higher levels of performance at a faster rate than low-ability trainees. However, contrary to Hypothesis 7, the interaction between session and partner ability was not statistically significant nor was the three-way interaction between session, individual ability, and partner ability. To further explore the differences in the growth curves, we examined the extent to which the linear and quadratic trends differed as a function of individual ability. The results indicated that both the linear and quadratic trends differed as a function of individual ability. Specifically, both the linear (t (1988) = 3.79, p < .001) and quadratic (t (1988) = 2.79, p < .01) trends were stronger for high-ability trainees (linear b = 1109.38; quadratic b = –52.34) than for low-ability trainees (linear b = 824.12; quadratic b = –36.97). In sum, high-ability trainees acquired skill at a faster rate and approached performance plateaus sooner than low-ability trainees.

Table 4. *Partner Effects as a Function of Trainee Ability*

SF individual test performance	H_H versus H_L		L_H versus L_L	
	t	*d*	*t*	*d*
Session 1	2.36**	0.50	-0.83	-0.20
Session 2	1.64	0.37	0.36	0.08
Session 3	1.56	0.35	0.48	0.10
Session 4	1.75*	0.40	0.24	0.05
Session 5	1.75*	0.40	0.57	0.13
Session 6	1.84*	0.43	0.88	0.20
Session 7	1.91*	0.44	1.09	0.24
Session 8	1.48	0.34	0.66	0.15
Session 9	1.56	0.37	0.88	0.21
Session 10	1.79*	0.42	0.62	0.15
Session 11	1.50	0.36	0.73	0.17
Session 12	1.76*	0.42	0.98	0.24
Mean across sessions	1.96*	0.47	0.69	0.16

Note. SF = Space Fortress. H_H versus H_L = high-ability trainees assigned to high-ability partners compared to high-ability trainees assigned to low-ability partners. L_H versus L_L = low-ability trainees assigned to high-ability partners compared to low-ability trainees assigned to low-ability partners. Values for t are based on the results when accounting for the random effects of the dyadic team. $^*p < .05$. $^{**}p < .01$. All significance tests are one-tailed.

Individual Perceptions of Team Interactions

Data for the team interaction variables were incomplete for six participants. Therefore, these participants were omitted from the following analyses. Overall descriptive statistics, intercorrelations between the team interaction variables, and correlations between the team interaction variables and average individual performance are shown in Table 5. Correlations between self- and partner-ratings were very strong for communication (r = .91) and cohesion (r = .94), but the correlation between self- and partner-ratings was moderate for leadership (r = .39). The average correlation between scales was .44 for trainee self-ratings and .41 for partner-ratings. All the correlations between perceptions of team interactions and individual performance were small. Further analyses broken down by training condition (i.e., partner assignments) suggested that the correlations between individual performance and team interactions differed depending on the training condition. Therefore, we present the correlations between average individual performance and all the team interaction variables for each of the four training conditions in Table 6.

Figure 3 shows the means for the team interaction variables for each training condition.

Table 5. *Overall Means, Standard Deviations, and Correlations for Team Interaction Variables*

Variable	*M*	*SD*	1	2	3	4	5	6
1. Average performance	2065.12	1589.60	---					
2. Communication – self	4.32	0.45	.11	---				
3. Communication – partner	4.32	0.45	.10	.91**	---			
4. Leadership – self	3.50	0.84	.17*	.35**	.29**	---		
5. Leadership – partner	3.31	0.81	-.18*	.20**	.26**	.39**	---	
6. Cohesion – self	4.23	0.55	.11	.68**	.68**	.28**	.35**	---
7. Cohesion – partner	4.17	0.55	.15*	.69**	.68**	.34**	.29**	.94**

Note. Total sample. N = 170. *p < .05. **p < .01. All significance tests are two-tailed.

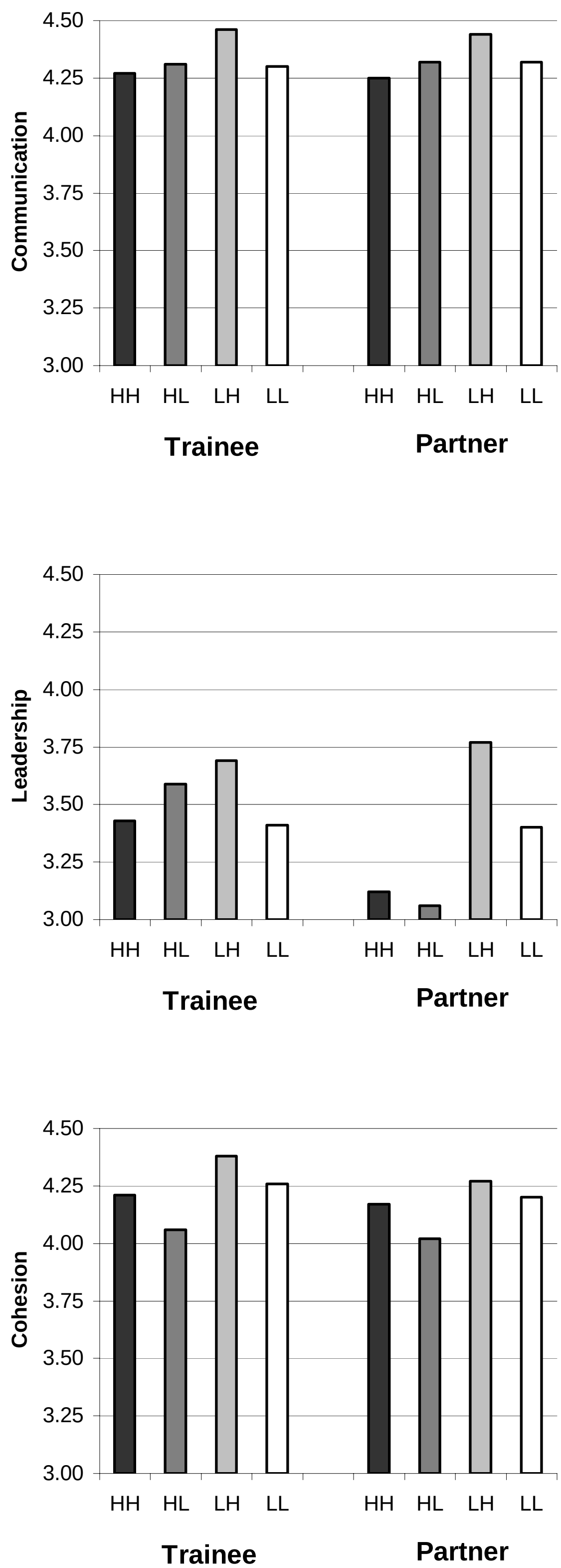

Figure 3.Means for the team interaction variables for each training condition.

Table 6. *Correlations between Average Training Performance and Team Interactions by Partner Assignment*

Variable	H_H	H_L	L_H	L_L
Communication – self	.22†	.07	.43*	-.07
Communication – partner	.19	.14	.46*	-.10
Leadership – self	.27*	.43*	.12	.06
Leadership – partner	.00	.07	-.06	-.35*
Cohesion – self	.25†	.25	.34†	-.12
Cohesion – partner	.35**	.25	.24	-.08

Note. H_H = high-ability trainees assigned to high-ability partners (n = 58). H_L = high-ability trainees assigned to low-ability partners (n = 31). L_H = low-ability trainees assigned to high-ability partners (n = 31). L_L = low-ability trainees assigned to low-ability partners (n = 50). †$p < .10$, *$p < .05$, **$p < .01$. All significance tests are two-tailed.

Effects of partner assignments. To address Hypotheses 8 through 11, we used the SAS MIXED procedure and treated dyadic team as a random effects variable. We then examined fixed effects for individual ability (high versus low), partner ability (high versus low), target of ratings (self versus partner), and all corresponding interactions. Because we had no theoretical reason to expect differences to vary across administrations, we collapsed the team interaction data across the four separate administrations[2].

Although the results revealed a statistically significant random effect for dyadic team (z = 5.49, $p < .001$), no other statistically significant effects were found for communication. Contrary to Hypothesis 8, a planned comparison did not indicate lower ratings of communication from trainees in mixed-ability teams compared to trainees from homogeneous teams. In fact, trainees across all conditions reported fairly high levels of communication (all means were greater than 4.24) with H_L and L_H trainees reporting slightly higher levels than other trainees.

In contrast to the ratings made for communication, the means for leadership varied across conditions and were generally much lower (all means were less than 3.80). The results revealed a statistically significant random effect for dyad team, $z = 2.62$, $p < .001$. A between-subjects main

[2] The results of the analyses when the team interaction data were not collapsed across administrations did not reveal any consistent or meaningful patterns.

effect indicated that low-ability trainees reported higher levels of leadership within their dyads compared to high-ability trainees, F (1, 114) = 6.41, $p < .05$, $\eta^2 = .05$. A within-subjects main effect indicated that overall self-ratings of leadership were higher than partner-ratings, F (1, 219) = 5.34, $p < .05$, $\eta^2 = .02$. However, these main effects were qualified by a statistically significant interaction between target and individual ability, F (1, 219) = 7.73, $p < .01$, $\eta^2 = .03$. Although low-ability trainees in general did not rate themselves differently on leadership compared to high-ability trainees, low-ability trainees reported higher levels of leadership for their partners compared to high-ability trainees. Specifically, and in support of Hypothesis 9, L_H trainees reported higher levels of leadership in their partners compared to all other trainees, t (114) = 4.03, $p < .001$, $d = 0.72$. In contrast, Hypothesis 10 was not supported—H_L trainees did not rate themselves higher on leadership compared to other trainees. No other statistically significant effects were observed for leadership.

Similar to the results for communication, ratings of cohesion within teams were fairly high across training conditions (all means were greater than 4.00). The results revealed a statistically significant random effect for dyad team, $z = 5.89$, $p < .001$. Although the exploratory analysis did not reveal any statistically significant effects, the results of a planned comparison supported Hypothesis 11 indicating that H_L trainees rated the cohesion in their teams lower compared to other trainees, t (114) = –2.03, $p < .05$, $d = –0.36$.

Correlations with individual performance. As shown in Table 6, the correlations between perceptions of team interactions and individual training performance varied across the different partner assignments. In support of Hypothesis 12, the correlations between communication and performance were stronger for H_L trainees than for other trainees. To test the statistical significance of these differences, we collapsed self- and partner-ratings into a single index of communication and then compared the correlation for H_L trainees to the average of the correlations across the remaining conditions. The results indicated that the difference in communication-performance correlations was statistically significant, $z = 1.95$, $p < .05$, one-tailed. In contrast, the results did not support Hypotheses 13 and 14. That is, the correlation between self-ratings of leadership and performance for H_L trainees was not significantly larger than the correlations across the other training conditions, and the correlation between partner-ratings of leadership and performance for L_H trainees was not significantly larger than the correlations for other trainees. In fact, and not as predicted, the correlation between partner-ratings of leadership and performance was statistically significant and negative for L_L trainees in contrast to the other training conditions, $z = –2.12$, $p < .05$. Lastly, the results also indicated that cohesion was positively related to performance across the training conditions with the exception of L_L trainees, $z = 2.25$, $p < .05$.

DISCUSSION

The purpose of the present study was to extend the small body of research that has formally manipulated the ability-based composition of training teams. At the dyadic-team level, we replicated the strong additive effects of ability demonstrated by Tziner and Eden (1985). Uniformly high-ability teams outperformed mixed-ability teams, who in turn outperformed uniformly low-ability teams. Moreover, the results of our growth curve analysis showed that higher-ability teams not only achieved higher levels of performance, but they also improved their performance at a faster rate than lower-ability teams. It is also important to note that the quadratic effects for the mixed- and low-ability teams, albeit less dramatic than for the high-ability teams, were strong enough to suggest that simply extending the length of training would not lead to more comparable performance levels across different ability compositions. Although the performance effects were in the expected direction, we obtained less conclusive findings regarding the potential synergistic effects of uniformly high-ability teams. That is, the difference in performance between uniformly high-ability teams and mixed teams was greater than the difference in performance between mixed-ability teams and low-ability teams; however, the direct comparison of these differences did not reach statistical significance. Nevertheless, our results are consistent with the notion that uniformly high-ability teams can achieve performance levels beyond that expected by summing the abilities of individual team members. In terms of binomial effect size displays (Rosenthal & Rubin, 1982), our results suggest that uniformly high-ability teams are 59% more likely to achieve success in training compared to uniformly low-ability teams, whereas the probability in success for mixed-ability teams is only 25% greater. Given the lack of studies that have addressed synergistic effects of ability with *a priori* designs, we believe that this study makes a contribution to the literature on team performance.

This study also extends the literature pertaining to ability-based pairing strategies and individual learning. Because the vast majority of studies appearing in the cooperative learning literature have focused on children's achievement on relatively simple tasks, this study makes an important contribution to the literature by focusing on complex skill acquisition in an adult sample. Our results suggest that the ability of a training partner can influence a trainee's acquisition of a complex skill, depending on the ability of the trainee. Specifically, the performance of low-ability trainees was not much better when they trained with high-ability partners compared to training with other low-ability partners, but the performance of high-ability trainees was significantly higher when they trained with other high-ability partners compared to training with low-ability partners. In fact, our results suggest that training with a high-ability partner increases the probability of achieving success in training by 23% for high-ability trainees, but for low-ability trainees the chances for success only increase by 8%. However, the lack of partner effects from our growth curve analysis showed that these partner effects were observed at the onset of training and remained constant throughout training.

Consistent with previous research (Fuchs et al., 1998), the difference in partner effects between high- and low-ability individuals may stem from the nature of the interactions that took place between partners during training. Our results showed that high-ability trainees who were paired with low-ability partners reported the lowest levels of cohesion within their dyads. This finding is important considering that our results also showed that cohesion was positively correlated with individual performance, except for low-ability individuals who trained with low-ability partners. Furthermore, the positive correlation between individual skill acquisition and ratings of communication for low-ability trainees who trained with high-ability partners highlights the importance of effective communication between partners for low-ability trainees in heterogeneous training teams. In other words, the extent to which low-ability trainees learn in mixed-ability training teams may be a function of the communication patterns that take place between trainees. However, this observed relationship was correlational in nature; thus, causal conclusions should not be made about these results. For instance, one could conclude that early performance successes led to improved cohesion and communication rather than higher levels of cohesion and communication led to performance improvements.

Implications

Given the extensive use of team-based training and instruction, the results of this study have practical implications. First, if the goal of team-based training is for a select few to reach exceptionally high levels of skilled performance, then training practitioners should pair high-ability trainees with other high-ability trainees to maximize the training environment for those trainees who are most likely to attain skill mastery. Moreover, our results suggest that homogeneous pairing strategies may not adversely affect the learning of low-ability trainees. However, the results of our interaction data also suggest that structuring the interactions between training partners may enhance learning within mixed-ability training teams. Specifically, trainees could be taught how to effectively communicate and interact with each other in order to foster clear communication, positive exchange of ideas, and commitment to one another.

Second, in instances where team-training protocols are used, our findings have potential legal and logistical implications for using training performance as a criterion or predictor in human resource management decisions. Specifically, the issue is one of making individual-level decisions based on performance outcomes that are partially influenced by factors (e.g., partner's ability) over which the individual has no control. Consequently, to resolve the confound of a training partner's ability on the trainee's individual performance, personnel specialists may have to consider controlling for the influence of other team members' abilities when using training performance in personnel decisions. Otherwise, using training performance as a criterion or predictor under these circumstances may not be appropriate.

Limitations and Future Research

Certain methodological factors limit the generalizability of our findings and provide insight into future research needs. First, this was a laboratory investigation that utilized a sample of young adult males, who were all right-handed. Firmer conclusions regarding generalizability of our results to a broader adult population require replications from field studies with older samples consisting of left- and right-handed males and females (cf. Sanchez-Ku & Arthur, 2000). Second, we used a normative mean to create teams of different ability compositions that was based entirely on a college sample and we restricted participation to only high- and low-ability individuals. As such, future research investigating the generalizability of our findings to non-college samples, covering the whole range of ability compositions with larger sized training teams, is warranted. Because our manipulation involved extreme differences, smaller effects could be observed with dyadic teams that have less disparity in member ability.

Given that researchers (e.g., Fuchs et al., 1998) have recently suggested that the influence of various grouping strategies may be moderated by task complexity, conclusions regarding our results may also be limited to complex tasks involving strong cognitive and psychomotor demands. Therefore, to expand our understanding of how to best form training teams, we recommend that researchers investigate the effects of task complexity and other task factors in future experiments. Researchers should also examine the extent to which the effects of ability composition may be moderated by group processes by manipulating the nature of interaction patterns within training teams. Because we examined the relationships between team interactions and individual performance using correlational data, cause-and-effect conclusions should not be made. Future studies that explicitly manipulate the nature of team interactions as well as the ability composition of training teams would provide more tenable causal conclusions regarding the relationships shared between the ability composition of training teams, team processes during training, team effectiveness, and individual training outcomes.

Another limitation of this study is that our criteria only included assessments of performance during and at the end of training. Not only do we recommend that researchers expand outcome measures to tests of long-term skill retention and transfer (Arthur, Day, Bennett, McNelly, & Jordan, 1997; Schmidt & Bjork, 1992), we also believe future studies should examine the extent to which different pairing strategies used during training influence how well individuals are able to later work with new partners. High-ability individuals may benefit from training with high-ability partners in terms of immediate performance, but how well can they adapt in future situations when they are paired with less capable partners? Although mixed-ability pairing strategies may not maximize training performance, mixed-ability strategies could help individuals learn to perform with partners of differing ability levels. Thus, we recommend that tests of transfer include ability-based partner assignments that differ from what individuals were exposed to during training.

Lastly, future research should also include trainee characteristics that are not ability related, such as personality and motivation, in order to further expand our understanding of composition effects on learning outcomes in team-training contexts. For instance, differences in goal orientation could influence the extent to which either immediate performance or long-term skill development is made at the expense of the other (Bunderson, & Sutcliffe, 2003; Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000). In particular, training teams emphasizing a mastery orientation could enrich efficacy beliefs at both team and individual levels, which in turn could enhance performance in more difficult, transfer situations (Kozlowski, Gully, Brown, Salas, & Nason, 2001). Furthermore, we would expect the influence of goal orientation to be moderated by the ability composition of the training teams (Bell & Kozlowski, 2002).

In sum, we created homogeneous and heterogeneous dyadic training teams on the basis of *g* to examine how team composition affects the acquisition and performance of a complex skill at both team and individual levels. Participants practiced in pairs and completed tests of both team and individual performance. Given the paucity of studies that have examined effects associated with ability-based manipulations of team composition in training contexts, the present study makes an important contribution to both team performance and cooperative learning literatures. Consistent with Tziner and Eden's (1985) seminal work, we found a strong additive influence of ability on team performance. Uniformly high-ability teams outperformed mixed-ability teams, who in turn outperformed uniformly low-ability teams. Contrary to Tziner and Eden (1985), we found only modest, statistically nonsignificant, synergistic gains in performance for uniformly high-ability teams. At the individual level, high-ability trainees acquired significantly more skill when paired with other high-ability partners instead of low-ability partners; however, low-ability trainees benefited only slightly from being paired with high-ability partners. Accordingly, we recommend that training specialists pay close attention to how trainees are assigned to training teams on the basis of their abilities to facilitate attainment of specified training objectives. For example, if the goal of training is to produce a subset of elite performers from a larger group of trainees, then we recommend that high-ability trainees train together and likewise perform together in post-training environments. However, if the goal is to ensure that all trainees reach some minimal level of proficiency, then using mixed-ability teams may be more appropriate, particularly if the post-training goals involve ensuring that all teams are performing at some minimal level of competence.

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